Monitoring Part 1: CEMS & Excepted Monitoring Options

Louisville, KY

July 25, 2001

Matthew Boze

Part 1 Overview

- CEMS
  - System Types
  - Performance Specifications
- Excepted Options
  - Appendix D - Heat Input Rate from Fuel Flow Meters
  - Appendix E - NO_x Emission Rate Estimation Procedures
  - LME - Default NO_x Rate for Low Mass Emission Units

Monitoring Requirements - Subpart H Monitoring

- NO_x Mass Emissions (lb/hr)

- NO_x Emission Rate (lb/mmBtu)
  - Required only if unit monitors NO_x Emission Rate and Heat Input Rate to determine the NO_x Mass Emissions

- Heat Input (mmBtu/hr)
  - Required only if unit monitors NO_x Emission Rate and Heat Input Rate to determine NO_x Mass Emissions, or
  - If required by State Rule, or
  - If the unit is subject to the requirements of 40 CFR 97 (§126 units)

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Monitoring Options for Determining NO_x Mass Emissions (Tons NO_x)

- NO_x Concentration (ppm) & Stack Flow Rate (scfh)

- NO_x Emission Rate (lb/mmBtu) & Heat Input Rate (mmBtu/hr)
  - NO_x Emission Rate
    - » NO_x Concentration & Diluent (%CO2 or O2), or
    - » Part 75, Appendix E (for gas or oil fired peaking units)
  - Heat Input Rate
    - » Stack Flow & Diluent (%CO2 or O2), or
    - » Fuel flow monitoring via Part 75, Appendix D

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Monitoring Options for Determining NO_x Mass Emissions (Tons NO_x)

- Low Mass Emissions Excepted Methodology
  - Default NO_x Emission Rate or Fuel-and-unit specific NO_x Emission Rate
  - Default Heat Input Rate or Long Term Fuel Flow

CEMS and Excepted Monitoring Systems

CEMS	Excepted CMS	
➢ NO_x-Diluent CEMS (NO_x monitor & CO_2 or O2 monitor, for NO_x emission rate) ➢ NO_x concentration system ➢ Stack volumetric flow monitoring systems	➢ Part 75, Appendix D fuel flow monitoring (Gas & Oil units only) ➢ Part 75, Appendix E NO_x Emissions Estimation (Gas & Oil Peaking units only)	Data Acquisition and Handling System (DAHS) Required
	➢ Low Mass Emissions Unit Methodology (Gas & Oil units only)	No DAHS Required

Data Reduction for CEMS with Diluent Components

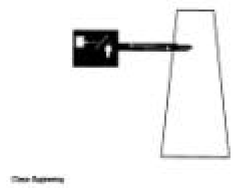
- NO_x Emission Rate via NO_x Concentration Analyzer & CO_2 or O_2 Diluent Concentration Analyzer
  - Part 75, Appendix F § 3, provides the equations that are used to compute NO_x emission rate (lb/mmBtu) given:
    - » NO_x concentration
    - » CO_2 or O_2 concentration
    - » F-factor for the fuel combusted
- Heat Input Rate via Stack Flow Monitor & CO_2 or O_2 Diluent Concentration Analyzer
  - Part 75, Appendix F § 5, provides the equations that are used to compute heat input rate (mmBtu/hr) given:
    - » Volumetric Stack flow
    - » CO_2 or O_2 concentration
    - » F-factor for the fuel combusted

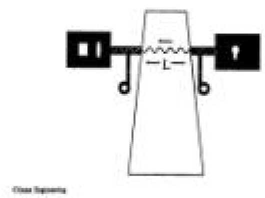
CEMS Options

- In-situ (Wet Basis measurement in the stack)
  - Point
  - Path
- Straight Extractive (Wet or Dry Basis Measurement)
  - Hot Wet - Wet Basis
  - Cool Dry with condenser near the CEMS Shelter - Dry Basis
  - Cool Dry with condenser at the probe - Dry Basis
- Dilution Extractive (Wet Basis Measurement)
  - In Stack Dilution
  - Out of Stack Dilution

In-Situ CEMS

- Point
  - Electro-optical, or
  - Electrochemical sensor
  - Measurement over short distant (~cm)
- Path
  - Light or sound is transmitted across the stack
  - The interaction with the stack gas is related back to a gas characteristic





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In-Situ CEMS

- Typical Applications:
  - Opacity Measurement
    - » Path - Light
  - Stack Flow
    - » Point - Differential Pressure (s-type Pitot)
    - » Path - Ultra-sonic (sound waves)

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In-Situ CEMS

- Advantages
  - Lower cost
  - Compact
  - No CEMS Shelter
- Disadvantages
  - All analytical components on the stack
    - » More difficult to maintain and quality assure
    - » Analytical components exposed to harsh stack conditions
  - Many In-Situ CEMS do not accept calibration gas for calibration

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Extractive Systems

- Representative sample of the flue gas is removed from the stack, transported to a CEMS shelter and analyzed
- Components of an extractive system
  - Probe
  - Sample lines
  - Filters
  - Moisture removal system
  - Pump
  - Analyzer
- Advantages
  - Easy analyzer access for maintenance and adjustments
  - CEMS shelter provides for good instrument life
  - Calibration with gaseous standards possible

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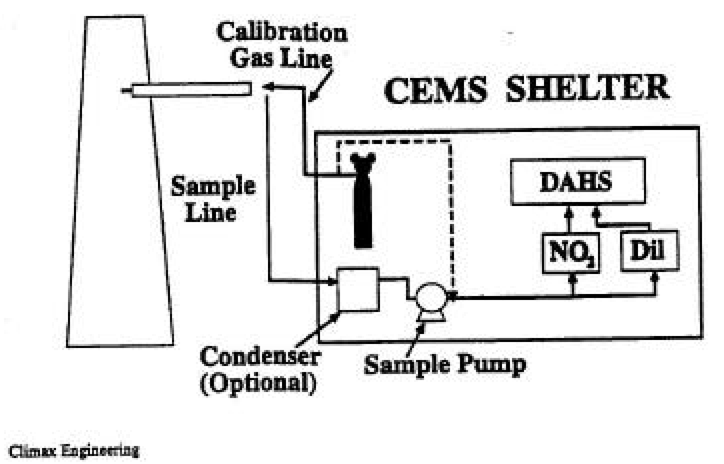
Conventional Extractive CEMS



Hot Wet Extractive CEMS

- No condenser so moisture remains in the system throughout the sampling and measurement process
  - Heated sample line, pump and analytical chamber required to keep the wet sample above its dew-point
  - Sample is analyzed hot and wet
- Analyzers must be insensitive to sample moisture content

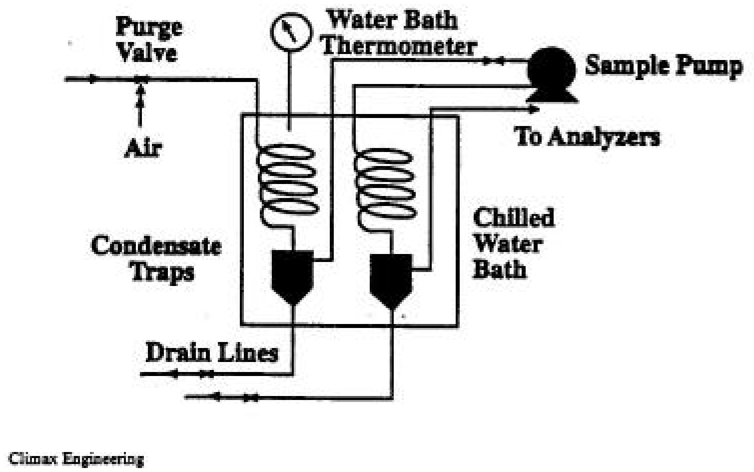
Hot Wet Extractive CEMS

- Advantage:
  - Water soluble gases including some VOCs can be measured without potential losses in the condenser system
- Disadvantage:
  - Heated line, pump, and analytical chamber are critical to system performance. A failure can result in corrosion, plugging, and damage to the system

Cool Dry Extractive CEMS

- Flue gas is collected and passed through a condenser to remove moisture prior to analysis
- Two Options
  - Conditioning at CEMS Shelter
    - Heated sample line required to keep the wet sample above its dew-point until it reaches the condenser
  - Conditioning at the stack
    - No heated line
    - however maintenance is difficult since the conditioning components are on the stack

Typical CEMS Condenser



Cool Dry Extractive CEMS

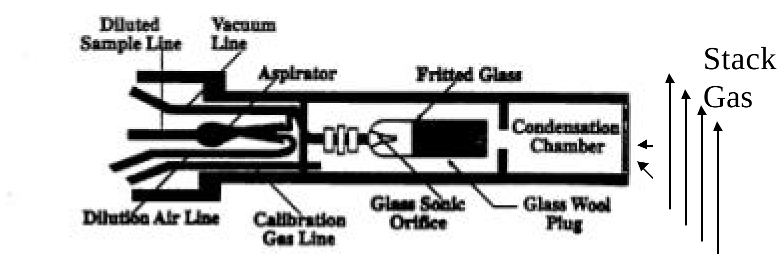
- Advantage:
  - greater flexibility in the choice of analyzers (ie, heated chamber not required)
  - Moisture interferences in the analytical components minimized
- Disadvantage:
  - Conditioning system maintenance required
  - Possible low bias due to scrubbing of pollutant from sample in the condenser
    - » May lead to failed RATA tests or Bias test and necessitate a BAF
    - » Care required to minimize losses of analyte in the condensate
  - Results may need to be adjusted to a wet basis for calculations

Dilution Extractive CEMS (wet basis)

- Flue gas is diluted with clean dry air to lower the dew-point of the sample
  - Eliminates the need for
    - Heated sample lines
    - Moisture removal system
- Dilution ratio is controlled by creating sonic flow across a critical orifice
  - Sonic flow of sample is maintained by achieving a set pressure drop across the critical orifice.
  - Sonic flow also depends upon
    - Molecular Weight of the sample
    - Pressure
    - Temperature

In Stack Dilution (dilution probe)

- Critical Orifice is in the probe
- Sample Temperature is Stack Temperature
- Quicker response than out of stack dilution
- No temperature controls to maintain



Climax Engineering

Out of Stack Dilution (separate dilution unit)

- Critical Orifice is separate from the probe and outside of the stack
- Temperature must be controlled by heating
- Slower response
- Easier to replace Critical Orifice

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Dilution Extractive CEMS (wet basis)

- Advantage:
  - No moisture transport/removal issues
    - » No loss of sample due to moisture removal
    - » No need for heated sample line after the sample is diluted
- Disadvantage:
  - Dilution Probe effects may bias measurement
    - » Effects for Molecular Weight can be minimized by calibrating the system with protocol gases which possess a MW representative of the flue gas
    - » Usually highly dependent upon the CO_2 concentration
    - » Bias can be both positive and negative

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Gas Measurement Principles

- Common Analytical NO_x Measurement Techniques
  - Chemiluminescence (NO)
  - Differential Ultraviolet Absorption (NO_2)
- Diluent Techniques
  - CO_2
    - » Non-Dispersive Infrared (NDIR)
    - » Gas filter correlation (GFC)
  - O_2
    - » Electrocatalytic
    - » Micro Electrochemical Fuel Cell

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NO_x Chemiluminescence Analyzers

- Detects the light given off by the following chemical reaction
  - $NO + O_3 \rightarrow NO_2^* + O_2$
  - $NO_2^* \rightarrow NO_2 + h\nu$
- All NO_2 must first be converted to NO for the above light emitting reaction to take place
  - Stainless Steel catalytic NO_x converter
- NO and NO_2 can be separately measured by enabling and disabling the catalytic NO_x converter
  - Converter "on" $\rightarrow$ Total NO_x
  - Converter "off" $\rightarrow$ NO
  - Total NO_x - NO $\rightarrow$ NO_2

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Monitoring Location Specifications for Pollutant and Diluent Gas Monitors

- Install system at a location where the measurements will be representative of total emissions for the unit (§3.1 PS2)
- System must be able to pass a RATA
- Point Monitors must measure
  - At a point within the centroid of the stack, or
  - No less than 1.0 meter from the stack wall

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Monitoring Location Specifications for Pollutant and Diluent Gas Monitors

- Path Monitors must measure
  - Within the inner area bounded by a line 1.0 meter from the stack wall, or
  - So that 70.0% of the path is within the inner 50.0% of the cross section, or
  - Such that the path crosses through the centroid

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Performance Specifications for NO_x-Diluent Systems (App. A, § 3)

- 7-day Calibration Error (CE)
  - NO_x: CE ≤ 2.5% of Span or within 5 ppm of the reference gas
  - CO_2 or O_2: |R - A| ≤ 0.5% CO_2 or O_2
- Linearity Check
  - NO_x Linearity Error (LE): LE ≤ 5.0% of reference gas or within 5 ppm of the reference gas
  - CO_2 or O_2: LE ≤ 5.0% of reference gas or within 0.5% CO_2 or O_2 of the reference gas
  - NO_x analyzer is exempt if span ≤ 30 ppm
- Cycle Time Test
  - Test NO_x and diluent analyzers separately (upscale and downscale)
  - Cycle time for NO_x-diluent system = slowest of the analyzers' cycle times
  - System Cycle Time ≤ 15 minutes

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Performance Specifications for NO_x-Diluent Systems (App. A, § 3)

- Relative Accuracy:
  - RA calculated on a 'lb/mmBtu' basis
  - RA ≤ 10.0% or within 0.020 lb/mmBtu of the average reference value
- Bias Test:
  - No system shall be biased low as determined by the test procedure in § 7.6 of Appendix A
  - A Bias Adjustment Factor (BAF) is applied to the NO_x emission rate data whenever a low bias is detected

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Performance Specifications for NO_x Concentration Systems (App. A, § 3)

- 7-day Calibration Error (CE)
  - CE $\leq$ 2.5% of Span or within 5 ppm of the reference gas
- Linearity Check
  - LE $\leq$ 5.0% of reference gas or within 5 ppm of the reference gas
  - NO_x analyzer is exempt if span $\leq$ 30 ppm
- Cycle Time Test
  - Perform upscale and downscale tests
  - System Cycle Time $\leq$ 15 minutes

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Performance Specifications for NO_x Concentration Systems (App. A, § 3)

- Relative Accuracy:
  - RA calculated on a 'ppm' basis
  - RA $\leq$ 10.0% or within 15.0 ppm of the average reference value
- Bias Test:
  - No system shall be biased low as determined by the test procedure in § 7.6 of Appendix A
  - A Bias Adjustment Factor (BAF) is applied to the NO_x concentration data whenever a low bias is detected

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On-Going Quality Assurance for Gas Monitors (App. B, § 2.1-2.2)

- Daily Calibration Error Check (§ 2.1)
  - NO_x: CE $\leq$ 5.0% of span or within 10* ppm of the reference gas
  - CO_2 or O_2: CE $\leq$ 1.0% CO_2 or O_2
- Quarterly Linearity Check (§ 2.2)
  - NO_x: LE $\leq$ 5.0 % or within 5 ppm of the reference gas
  - CO_2 or O_2: LE $\leq$ 5.0 % or within 0.5% of the reference gas
  - For NO_x-diluent systems, both analyzers must be checked

* Proposed Rule Change to 5 ppm

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On-Going Quality Assurance for Gas Monitors (App. B, § 2.3)

- Addresses Semiannual & Annual Assessments
- Relative Accuracy Test Audit (RATA)
  - NO_x-diluent systems
    - » Semiannual - 7.5% < RA $\leq$ 10.0% or $\pm$ 0.020 lb/mmBtu
    - » Annual - RA $\leq$ 7.5% or $\pm$ 0.015 lb/mmBtu
    - » Ozone Season only reporters, see §75.74(c)

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On-Going Quality Assurance for Gas Monitors (App. B, § 2.3)

- RATA (cont.)
  - NO_x concentration systems
    - » Semiannual - 7.5% < RA $\leq$ 10.0% or $\pm$ 15.0 ppm
    - » Annual - RA $\leq$ 7.5% or $\pm$ 12.0 ppm
    - » Ozone Season only reporters, see §75.74(c)
- Bias Test
  - No NO_x-diluent or NO_x concentration system shall be bias low
  - Apply BAF to subsequent data if negative bias is detected

Stack Volumetric Flow Rate Monitoring

- Differential Pressure
  - S-Type Pitot
  - Annubar
- Acoustic Sensing
  - Ultrasonic
  - Audible Sensor
- Heat Transfer Sensing
  - Heat loss from a heated body to the flue

Monitoring Location Specifications for Stack Flow Monitors

- A flow monitor location is acceptable if either
  - the location satisfies the minimum siting criteria of method 1
    - » Locate 8 stack diameters downstream & 2 upstream of any disturbance
  - the results of a flow study are acceptable

- Also the flow monitor must be able to pass the required performance tests

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Performance Specifications for Stack Flow Monitors (App. A, § 3)

- 7-day Calibration Error:
  - CE $\leq$ 3% of Span or within 0.01 in H_2O of the reference value for differential pressure systems
- Relative Accuracy:
  - Test at 3 load levels for initial certification
  - RA $\leq$ 10.0% or within 2.0 fps of reference value
- Bias: No system shall be biased low as determined by the test procedure in § 7.6 of Appendix A
  - A Bias Adjustment Factor (BAF) is applied whenever a low bias is detected

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On-Going Quality Assurance for Stack Flow Monitoring Systems

- Part 75, Appendix B § 2.1 - Daily Assessments
  - Daily Flow Interference Check:
  - Daily Calibration Error Test (Differential Pressure Systems):
    - CE $\leq$ 6% of span or within 0.02" H_2O
- § 2.2 - Quarterly Assessments
  - Leak Check (Differential Pressure Systems)
  - Flow-to-Load Ratio or Gross Heat Rate evaluation

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On-Going Quality Assurance for Stack Flow Monitoring Systems

- § 2.3 - Semiannual & Annual Assessments
  - Relative Accuracy Test Audit (RATA)
    - Semiannual - 7.5% < RA $\leq$ 10.0%
    - Annual - RA $\leq$ 7.5% or within $\pm$ 1.5 fps of the reference value
    - Ozone season only reporters, see §75.74(c)

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Excepted CMS

- Part 75, Appendix D
  - Protocol that may be used in lieu of flow monitoring systems for the purpose of determining the hourly heat input rate
  - Gas and Oil fired units only

- Part 75, Appendix E
  - Procedure that may be used in lieu of a continuous NO_x emissions monitoring system for determining hourly NO_x emission rate
  - Gas and Oil fired <u>peaking</u> units only
  - May qualify for peaking status on ozone season basis if unit reports in ozone season only
    See §75.74(c)(11)

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Excepted CMS

- Low Mass Emissions Unit Methodology (§75.19)
  - Procedure that may be used in lieu of CEMS or the excepted methods under App D and E for the purpose of determining hourly heat input and NO_x mass emissions
  - Natural gas and fuel oil only
  - NO_x emissions limitation
    - » Year round reporting units: $NO_x \leq 50$ tons/year
    - » Ozone season only reporting units: $NO_x \leq 25$ tons/control period

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Part 75, Appendix D

- Heat input rate (mmBtu/hr) is determined from the:
  - Fuel Flow Rate, and
  - Gross Calorific Value (GCV) of the fuel

$$HI_{rate} = \text{Fuel Flow Rate} * (GCV_{fuel} / 10^6)$$

Part 75, Appendix D (Fuel Flowmeters)

- Fuel Flowmeters
  - Must meet the fuel flowmeter accuracy specification for initial certification (App D § 2.1.5)
  - Visual inspection of orifice, nozzle, and venturi meters every 3 years
  - Must pass a fuel flowmeter accuracy test at least once every four QA operating quarters (App D § 2.1.6)
  - Fuel flowmeter accuracy $\leq$ 2% of the flowmeter's upper range value

Part 75, Appendix D (Fuel Flowmeters)

- Types of Fuel Flowmeters
  - Orifice Plate
  - Nozzle
  - Venturi
  - Coriolis
  - Others that meet the applicable specifications

Appendix D Basic GCV Fuel Sampling Options

- Oil Sampling
  - Flow proportional/weekly composite
  - Daily manual sampling
  - Storage tank sampling (after each addition)
  - As delivered (sample from delivery vessel)
- Gas Sampling
  - Monthly Samples (pipeline natural gas, or natural gas, or any gaseous fuel having demonstrated a "low GCV variability")
  - Daily or Hourly Samples (any gaseous fuel not having a "low GCV variability")
  - Lot sampling (upon receipt of each lot or shipment)

Part 75, Appendix E (Peaking Status)

- Applicable only to Gas and Oil-Fired Peaking Units
- Peaking unit (§ 72.2 - Definitions)
  - An average capacity factor of no more than 10.0% during the previous three calendar years and
  - A capacity factor of no more than 20.0% in each of those three calendar years
  - Ozone season only reporters can qualify on an ozone season only basis §75.74(c)(11)
- Initial qualification for peaking status by
  - Three years (or ozone season) of historical capacity factor data, or
  - For newer or new units, a combination of all historical capacity factor data available and projected capacity factor information

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Part 75, Appendix E (Peaking Status)

- For units that make a change in capacity factor may qualify by:
  - Collecting three calendar years of data following the change to meet the historical capacity factor specification, or
  - Collect one calendar year of data following the change showing a capacity factor of less than 10.0% and provide a statement that the change is considered permanent

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Part 75, Appendix E (Peaking Status)

- Units that hold peaking status must continue to meet both the 10% three year and 20% single year (or ozone season) criteria to retain peaking status
- If a unit fails to meet the criteria it must install & certify a NO_x CEM by January 1 of the year after the year for which the criteria are not met
- A unit may then re-qualify only by providing three new years (or ozone seasons) of qualifying capacity factor data

Part 75, Appendix E

- The average NO_x emission rate (lb/mmBtu) is determined from
  - Periodic fuel specific NO_x emission rate testing at four, equally spaced load levels
    - » Boilers
      - Method 7E for NO_x
      - Method 3A for the diluent
    - » Stationary gas turbines
      - Method 20 for NO_x
      - Method 3A for the diluent

Part 75, Appendix E

- Plot the NO_x Rate vs. Heat Input Rate
- Use the graph of the baseline correlation results to determine the NO_x emission rate corresponding to the heat input rate for the hour
  - – Linearly interpolate between reference points to the nearest 0.001 lb/mmBtu using heat input values rounded to the nearest 0.1 mmBtu/hr

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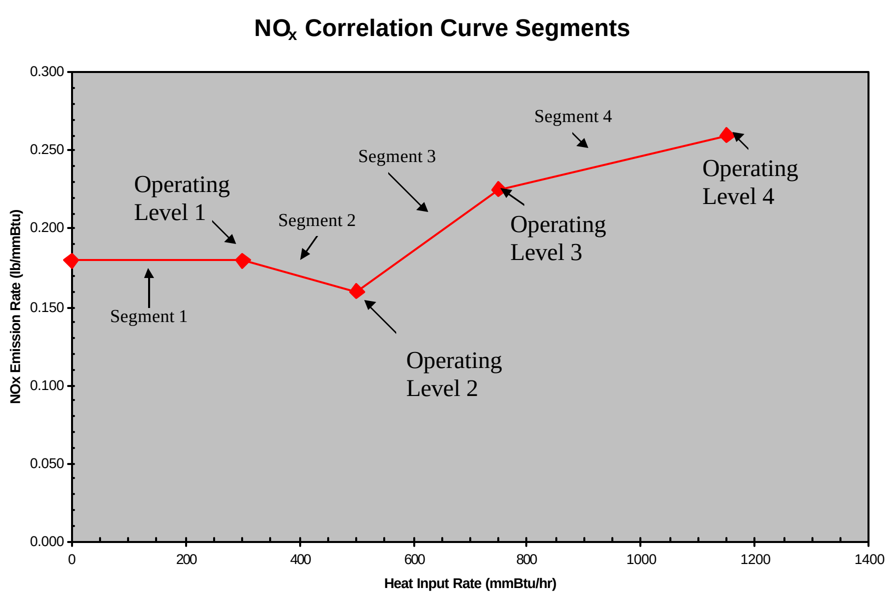

Low Mass Emissions Unit Methodology

- Applicability:
  - Natural Gas and Fuel oil combusting units only
  - An initial demonstration that the unit emits no more than 50 tons of NO_x per year, or 25 tons per control period for ozone season only reporters
  - An annual demonstration that the unit emits no more than 50 tons of NO_x per year, or 25 tons per control period for ozone season only reporters
- This methodology relies on
  - Either a Default NO_x emission rate or a Fuel-and-Unit Specific NO_x emission rate, and
  - Either Maximum Rated Hourly Heat Input for the unit or records of Long Term Fuel Flow

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LME - NO_x Emission Rate

- Default NO_x Emission Rate
  - Table LM-2 of §75.19(c)

Boiler Type	Fuel Type	NO_x Emission Rate (lb/mmBtu)
Turbine	Gas	0.7
Turbine	Oil	1.2
Boiler	Gas	1.5
Boiler	Oil	2

- Fuel-and-Unit Specific NO_x Emission Rate
  - Perform four load Appendix E testing
  - Use the highest NO_x emission rate from the testing multiplied by 1.15 or
  - 0.15 lb/mmBtu whichever is greater

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LME - Heat Input Rate

- Maximum Rated Heat Input Method
  - §72.2 defines the Maximum Rated Heat Input as “a unit-specific maximum hourly heat input (mmBtu) which is the higher of the manufacturer’s maximum rated heat input or the highest observed hourly heat input”
  - Total Heat Input for the quarter is the product of the number of operating hours and the Maximum Rated Heat Input

$$HI_{qtr} = OPHrs_{qtr} \text{ x } MRHI$$

LME - Heat Input Rate

- Long Term Fuel Flow Heat Input Method
  - Fuel Flow
    - » Qualified fuel billing records
    - » A fuel measurement standard listed in §75.19(c)(3)(ii)(B)(2), or
    - » A fuel flowmeter certified, maintained, and quality assured according to Part 75 Appendix D

LME - Heat Input Rate (LTFF Method)

- GCV
  - Part 75, Appendix D §2.2 and 2.3, or
  - Default GCV in Table LM-2
    - » Pipeline Natural Gas - 1050 Btu/scf
    - » Natural Gas - 1100 Btu/scf
    - » Residual Oil - 19,700 Btu/lb or 167,500 Btu/gal
    - » Diesel Fuel - 20,500 Btu/lb or 151,700 Btu/gal
- Total Heat Input is apportioned by load to each operating hour at the end of each reporting period
  - MDC has a module that helps in performing this task and generates EDR records for the electronic report (for single units only) - Contact Kim Nguyen

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